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PHOTOGRAPHIC OPTICS - A STATUS REPORT

BY

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Photographic lenses for pictorial photography: State of the art

In the more than 400 years since the inventions of photographic, photographic lenses have been designed in a multitude of forms ranging from the simplest meniscus lenses for box-type cameras to complicated systems. While there have been many short-lived designs, other lens types have controlled the market for half a century or more, so that many people believe that further improvements are handly possible.

However, this is not so. A new photographic lens is not created by the mere desire to devise a new system, determining a design formula which avoids the usual aberrations and then grinding the components accordingly. Today more than ever, the production of lenses is based on the solution of problems of material and workshop technique, if the lenses are not only to be better, but also economically competitive.

1. Single-element lenses

Single-element lenses, such as menisci for box-type cameras, have an enormous market, so that it is worthwhile to think about their economic manufacture; and it is not surprising that menisci are now primarily molded from plastics. It is no secret that plastics are not dimensionally stable, and for a long time the optical industry waited for special types of plastic which would not have this disadvantage. It has been found necessary to subject available types of plastic to

certain treatments both before moulding of the lenses and after their completion. Special drying and hardening processes, more of a workshop trick than a classical technique, lead to practically stable lenses which can even be coated. Instead of age shrinkage, as before, we now have to consider alternating swelling and shrinkage depending on climate, while another important factor is the relatively pronounced changes of optical and other material properties as a function of temperature.

Plastic single-element lenses are particularly economic due to the fact that they can be moulded with wide edges saving part of the mount or even of the shutter, thus facilitating design and assembly of the camera and reducing costs (Fig. 1).

The changes experienced by a modern plastic lens in the course of its life do not noticeably effect its performance which even under normal conditions is not higher than average. The future thus belongs to the plastic meniscus. Whether any photographically useful advantage can be gained by giving it an aspheric shape is still undecided.

2. Two-element lenses

The idea of making a two-element lens, for instance an achromat, of plastic in the conventional manner is very tempting because plastics are more easily available with favorable refractive indices and color dispersion than glass (Fig. 2). However, the difficulty of producing such an achromat is far greater than that of making a single-element lens because each of the components has a higher refractive power, i.e. more steeply curved surfaces, so that the two components are considerably more sensitive regarding their relative centering.

Owing to the fact that the correction of aberrations presents certain difficulties if the image is to be noticeably better or brighter than that of a simple meniscus, the lens designer will soon reach a dead end.

3. Three-element lenses

It appears more appropriate to study the subject of three-element lenses. These are today the standard lenses for amateur cameras in the medium price range, and ever since their invention by Taylor in 1892 their design has been continuously improved. It is not difficult to determine the optimum shape of a three-element lens of given aperture for given glass types or to find the maximum aperture for a certain, prescirbed performance. Progress made during the last war in the technique of glass melting made it possible to produce miniature three-element lenses with a speed of f/2.8. A further increase in aperture or other performance data will be possible to a noticeable extent only if lens material of considerably higher refractive indices becomes available.

Plastics have also imposed themselves in the manufacture of three-element lenses and have conquered the lower range of apertures up to about f/8 (Fig. 3). In view of the high-speed emulsions we have at our disposal even for color photography, this represents no serious handicap for shooting in countries where the sun is high in the sky, if we consider that the flashlight is available even for the usual amateur subject in adverse lighting conditions. Low-speed plastic three-element lenses have thus reached the same stage of technical development as the simple menisci described above. Here, improvements in the stability of the plastic material will definitely result in an increase in speed.

Simple lenses of this type, with their limited performance, are to be found only in amateur cameras.

4. Assymmetrical four-element lenses

Professional work with negative sizes of 2 1/4" x 2 1/4" is a field reserved for the assymmetrical, partly cemented four-element lens which conquered the world around the turn of the century and is today made under such names as Skopar, Tessar, Xenar, Ysarex, etc. Its aperture and angular field are not greater than that of a three-element lens designed with the same care, but its performance, particularly in the corners of the field, is considerably better. Progress in glass melting made it possible to increase the classical speed of f/6.3 to f/4.5 half a century ago, to f/3.5 after World War I and in our days to create a standard aperture of f/2.8 (Fig. 4) which has already been surpassed by one of f/2.4.

The high performance inherent in this type of lens permits an increase in focal length at medium speed and a coverage of sizes up to 7 1/8" x 9 1/2" and larger with a sufficient field margin. For 35mm photography, this type of lens still remains the medium-fast lens giving the best performance, and for professional photography, the moderately priced universal lens which covers larger negatives sizes as well.

5. Symmetrical four-element lenses

If very large negative sizes have to be employed, lenses of smaller aperture - about f/9 - with an angular field of approx. 45 degrees belonging to the symmetrical, uncemented types are more appropriate. Modern examples are process lenses, such as the Rodenstock Apo-Ronar (Fig. 5). Apochromatic correction is extremely important for long

focal lengths, since the residual chromatic aberration of normal achromats, i.e. the secondary spectrum, increases in proportion with the focal length, so that superior performance becomes impossible.

Symmetrical lenses offer maximum sharp definition on a scale of 1:1. This holds true at least approximately when such lenses are used for photos of inanimate objects, etc. Under practical conditions, however, the performance of these apochromats satisfies very exacting demands also for reproducing more distant objects, provided that they are stopped down; this is usually necessary in any case for reasons of depth of field. Apo-Ronar lenses of focal lengths up to 24" (600 mm) are therefore also available in between-the-lens shutters for taking purposes (Fig. 6). Further improvement of such highly developed lens types is slow: the improved curve of spherical aberration achieved in the course of several years (Fig. 7) can almost be considered as "progress by leaps and bounds".

Since in its present form, the potentialities of this four-element type are fully exploited, a further increase in aperture, field or focal length can be achieved only by the use of additional optical means, if the highest standard of definition is desired.

6. Six-element symmetrical lenses

Due to the ever higher requirements to be satisfied by photographic and process lenses regarding angular field and evenness of illumination, combined with long focus and high performance, the general trend is towards six-element systems, partly making use of classical designs and partly trying out new solutions (Fig. 8). Work in this direction is in full swing, and the results should be available in the near future.

6a. One of the problems encountered in this connection consists in maintaining focal length tolerances of 1 per mille or less in mass production in order to guarantee a minimum of adjustment for the automatic focusing controls of copy equipment. For this purpose, Rodenstock have developed special collimators for their testing laboratory (Fig. 9).

7. Assymmetrical systems of six and more elements.

This lens type, which is represented by the modified Gauss type or the Sonnar, is used above all with apertures around f/2 and wider for small negative sizes, and in the form of high-performance systems around f/2.8 to f/4 for medium sizes. The standard aperture of a good 50 mm miniature lens can today be considered to be f/1.9, combined with a back focal distance which leaves sufficient room for the mirror movement in reflex cameras.

The performance of these lens types can still be improved. It is, however, doubtful whether such an improvement would be noticed in practical work, owing to the unavoidable sources of error introduced by camera tolerances, film flattening and grain of the emulsion.

8. Ultra-fast lenses

These are special-purpose systems. Their development has recently been considerably stimulated by progress in the television field, for example by the necessity of recording very weak images from television camera tubes. These lenses are frequently used in pairs, in tandem arrangement, in order to project such images - if necessary, slightly magnified or reduced - from the fluorescent screen of an image converter tube onto the photocathode of a TV camera tube. In this

field there is still ample scope for the further development of photographic lenses, above all in view of image-formation by means of infrared radiation of short or long wavelength. An example for an aperture of f/0.75 is shown in Fig. 10, and for positive field curvature adapted to cathode ray tubes in Fig. 11. (Rodenstock designs and patents).

9. Mechanical requirements frequently impose the use of a higher number of lens components, such as the demand that the camera extension should remain short at long focal lengths. For more than half a century, <u>telephoto lenses</u> have been satisfying such demands. Nowadays they are used for miniature sizes with focal lengths up to about eight times the standard focus in order to comply with the requirements regarding stop position in cameras with behing-the-lens shutter.

These lenses are an example of the progress that has become possible due to advances in glass melting and the improved application of optical formulas in electronic computers.

Telephoto lenses are very popular for medium sizes, if the angular field does not exceed about 30 - 35°; the reduced overall length of the lens avoids camera extensions of more than arm's length with all their inconveniences of difficult operation, sensitivity to wind, etc. In addition, modern telephoto lenses are corrected chromatically, and astigmatically to such an extent that they can be used without reservation for color and close-up photography as well.

10. <u>Wide-angle lenses</u>

Since reflex cameras inexorably demand a long back focal distance exceeding the focal length even of a moderate wide-angle system, the retrofocus design characterized by a large meniscus-shaped dispersing

front lens is indispensable. This lens type has therefore become very popular for 35 mm and cine cameras; the mechanical requirements can be satisfied down to very short focal lengths. Such systems necessitate a relatively large number of elements. Compromises, such as the acceptance of a moderate aperture ratio or noticeable residual distortion, can today be avoided.

A set of modern interchangeable lenses of short to long focus for a reflex camera becomes more complicated in the same degree as the focal lengths approach extreme values (Fig. 12).

Commercially usable high-grade pictures taken with medium-size ground-glass-focusing cameras are required to be uniformly illuminated from the center to the edges. The radiation laws for photographic lenses then lead to designs in which the diaphragm is surrounded by positive lenses which in turn are followed by large meniscus-shaped negative lenses. With medium apertures and fields of up to 100°, these lenses evidence remarkably good definition and illumination from the center out to the corners; due to the high precision required, they cannot be inexpensive. Several renowned companies are busily engaged in perfecting these lens types (Fig. 13).

A set of lenses for the 2 1/4" x 3 1/4" size including wide-angle, normal-angle and telephoto lens may thus feature the most varied designs.

Such lenses for medium sizes still leave ample room for improvement. Photographers demand an uninterrupted series of focal lengths covering practically any negative size and permitting a wide choice of combinations of medium to large aperture ratios and standard or optimum performance in accordance with economical and technical requirements.

11. Soft focus lenses

Special soft-focus systems exhibit a considerable amount of spherical aberration whose effect on the image can be controlled by an appropriate diaphragm. The Rodenstock IMAGON (Fig. 15) is enjoying growing popularity for portraiture and advertising photography. Further developments-if at all necessary or possible - will be based on fashion, style and taste, so that they are at present unpredictable.

12. Variable-focus lenses for 35 mm and other sizes

These are likewise special-purpose systems with good prospects for the future.

Since systems of this type are necessarily very voluminous, far more so than a standard lens of medium focal length and identical aperture, the introduction of zoom lenses for larger than miniature or lower medium sizes can hardly be expected. They are manufactured on the one hand for standard performance covering a focus range to both sides of the standard focal length, and on the other hand for a wide range of telephoto focal lengths. Contrary to cine cameras, an ordinary reflex camera allows certain mechanical simplifications due to the possibility of ground-glass focusing; this circumstances promises that telephoto zoom systems will continue to be economical in the future. As a note of interest it may be added that there were interesting predecessors in Europe as early as the turn of the century (Fig. 16, Rodenstock).

13. Cine camera lenses of fixed focal length

What was said regarding still photography with small or large negative sizes by no means applies to cinematography of all sizes, including television.

Nowadays only very moderately priced amateur cameras are equipped with a lens of fixed focal length; this is usually a three-element fixed-focus lens which can satisfy only modest demands. Higher priced, and particularly special-purpose cameras use four to six-element lenses with apertures up to f/1.4; retrofocus designs are required for short focal lengths. With the exception of extremely long focal lengths, made possible for example by mirror lenses or ultra-wide apertures - as mentioned above - this development is already a thing of the past.

14. Cine camera lenses of variable focal length

Practically all modern cine and TV cameras are equipped with zoom lenses. The first variable-focus systems were developed for cine cameras both in America and in Europe in the period between the two world wars, for instance, the German Busch Vario-Glaukar for a 16 mm Siemens camera (Fig. 17). However, a more extensive development started only about 1950; the scope of this development is best illustrated by the fact that since then about 500 patents for variable-focus lenses have been granted in different parts of the world.

Brief mention should be made of a few standard designs of this type. Three groups of components (Fig. 18) may be used, of which the first, generally positive one is moved only a short distance during variation of the focal length. The second group of components is displaced over a considerable distance, while the third, multi-element group contains the diaphragm and is stationary. Lenses with a zoom ratio up to 1:4 and an aperture of f/1.8 for all cine film sizes are today designed on this principle.

If the aperture is to be increased to about f/1.4 and the zoom ratio to 1:6 or more, a larger number of elements is required, above all if part of thelight is to be reflected to the viewfinder for through-

if part of the light is to be reflected to the viewfinder for through-the-lens focusing. It is then necessary to use four groups of components of which the outer ones are stationary, while the inner ones are shifted in different ways (Fig. 19). This and similar designs are today undergoing further development particularly the mechanical probelms concerning component displacement while keeping diaphram planes stationary.

If certain compromises regarding image focus are made, a design in which converging components are displaced against diverging ones offers mechanical advantages; it is then possible to dispense with expensive guide cams, etc. These systems therefore have good prospects for the future (Fig. 20).

Whichever design may be used, the problem has been solved of making ultra-fast lenses - about f/1.4 - with a zoom ratio of at least 1:6, and lately even 1:10 and more, whose performance over the entire focal length range is at least equal to that of a normal standard lens of fixed focus. This statement applies to 16 mm film just as well as to commerical 35 mm film and all amateur sizes using 8 mm film.

15. Aspheric surfaces

The question has frequently been asked whether aspheric surfaces would be suited for general use to improve definition or to reduce the number of elements without loss of definition, i.e. to simplify the system. In accordance with the present state of the art, this question must be answered in the negative. It is true that by computation an image error can be largely or entirely corrected by an aspheric surface; this applies above all to spherical aberration

and curvature of field. However, such surfaces cannot, up to now, be made with the accuracy required for high-performance lenses, which on the other hand is easily obtainable with spherical surfaces thanks to their geometrical regularity, which is precisely the basis of lens grinding and polishing and of checking with the aid of optical flats. This is the reason why for several decades aspheric surfaces have really proved their value only in illumination systems. In the filed of photographic lenses, development has not progressed beyond a few suggestions and trials for their introduction; hand-made and individually corrected pieces are so expensive that they can be considered only for special purposes, but under no circumstances for general pictorial use.

16. Color transmission of lenses

In our days of color photography, uniform spectral transmission is of considerable importance for every single lens of a lens set, be it designed for 35 mm, large formats or cinematography. In other words: photos of the same object on the same photographic material should not show different hues. If ultraviolet-absorbing barrier filters are used, primarily in conjuction with reversal material, much has already been gained, even if two lenses should represent extreme conditions of transmission. The general tendency amoung lens manufacturers is to use almost or entirely color-free types of heavy glasses which formerly were rather yellowish, and to correct residual differences in color transmission by using an anti-reflection film of suitable tinge - in this case yellow.

Summarizing, it may be said that all average shooting problems are easily mastered by modern lenses. Particularly high demands are a

stimulus for further development. The satisfaction of extreme requirements, however, demands much time and trouble as well as considerable investment.

C a p t i o n s

for the article "Photographic lenses for pictorial photography: State of the art"

Fig. 1: Cross section through a plastic meniscus with moulded edge; from a German patent.

Fig. 2: The n,Ny-diagram for glasses (dots), deep flints (dots with circle) and plastics (squares).

Fig. 3: f/8 three-element plastic lens by Rodenstock

Fig. 4: Development of YSAREX four-element lens from f/6.3 to f/2.4

Fig. 5: The Rodenstock APO-RONAR in barrel.

Fig. 6: Rodenstock APO-RONAR lenses in between-lens-shutters for use in cameras.

Fig. 7: Improvement of spherical and chromatic correction of APO-RONAR lenses within a few years.

Fig. 8: Six-element Rodenstock APO-RONAR in barrel.

Fig. 9: Collimator for focal length calibration of process lenses (Rodenstock workshop photo).

Fig.10: f/0.75 lens for television purposes.

Fig.11: Lens with positive field curvature for cathode ray tubes

Fig.12: Lens set of approximately identical back focus for 35 mm cameras with between-the-lens shutter.

Fig.13: Rodenstock wide-angle lens GRANDAGON with 100° field.

Fig.14: Lens set for 3 1/4" x 2 1/4" size, consisting of wide-angle, normal-angle and telephoto lens.

Fig.15: The Rodenstock IMAGON in between-the-lens shutter, with interchangeable perforated disks.

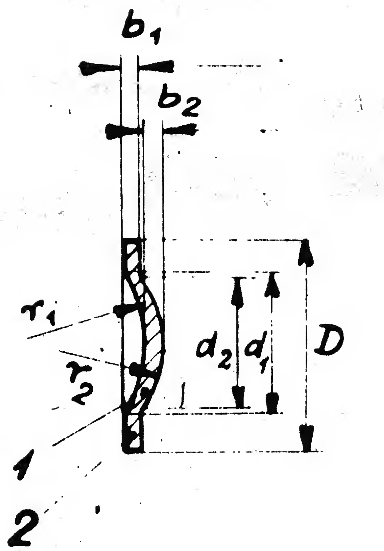
Fig.16: Rodenstock variable-focus telephoto lens from the turn of the century.

Fig.17: The Busch Vario-GLAUKAR, a zoom lens for 16 mm film from the year 1933.

Fig.18: Diagram of a zoom lens consisting of three groups of components.

Fig.19: Lens consisting of four groups of components, of which the inner ones are displaced along the nm-curves for variation of focal length. The dot-and-dash line represents the path of the nodal point.

Fig.20: Variable-focus lens with diverging elements for joint and identical displacement between the converging elements. From a French patent.



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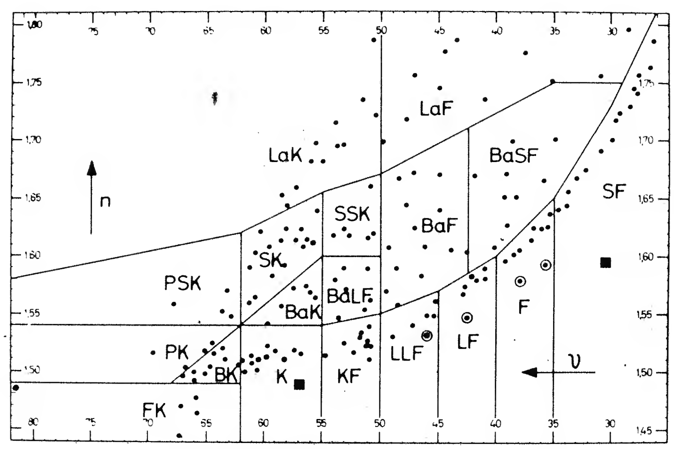

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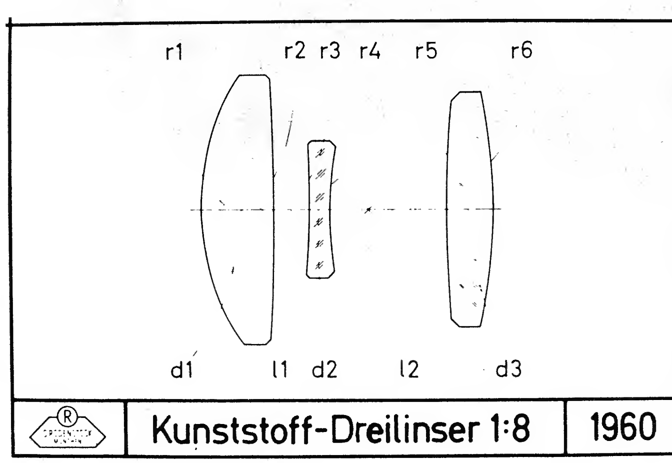

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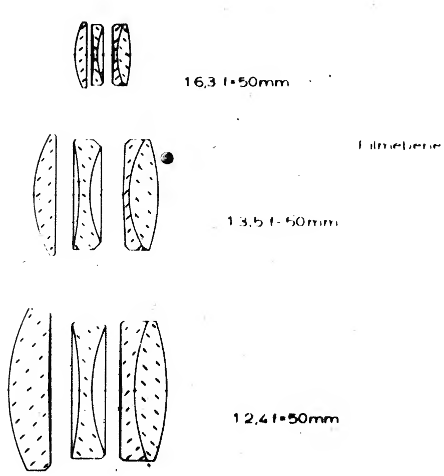

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12,4 f=50mm

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Rodenstock-Apo-Ronar

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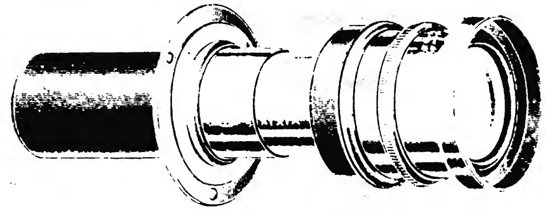
(Tele-Objektive.)



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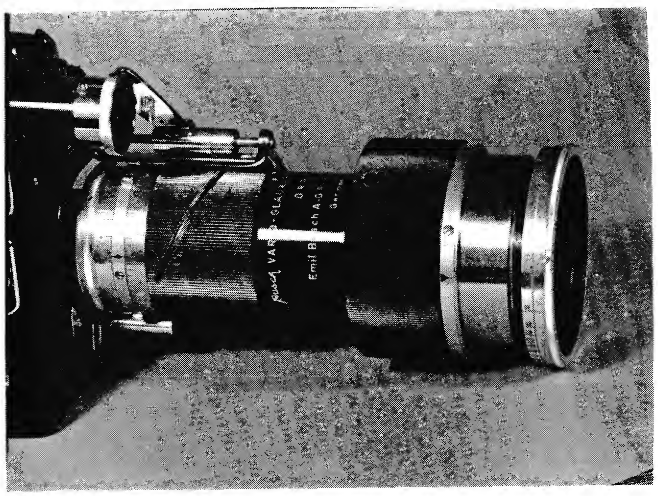

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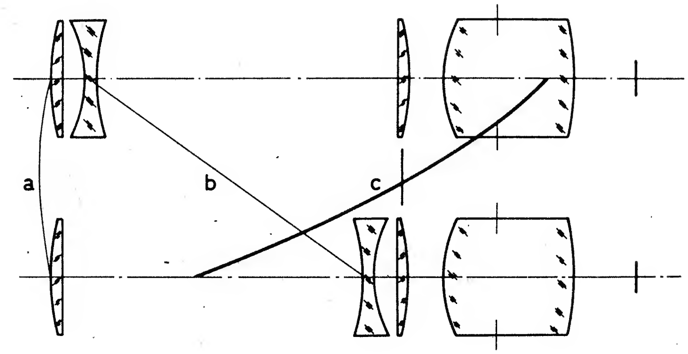

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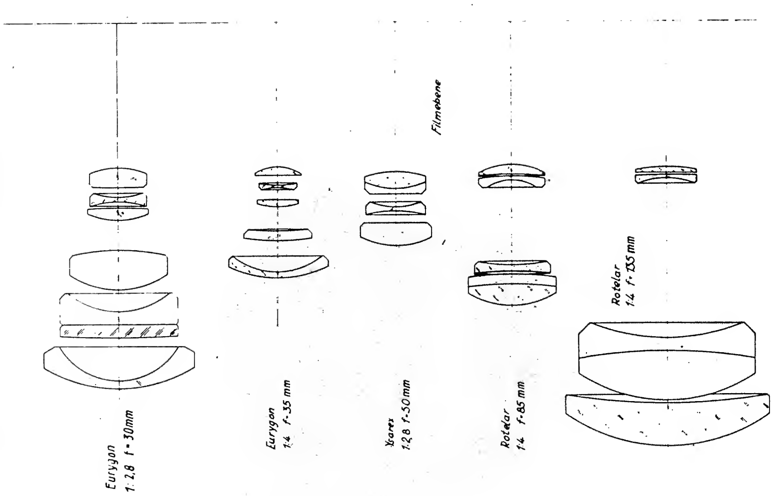

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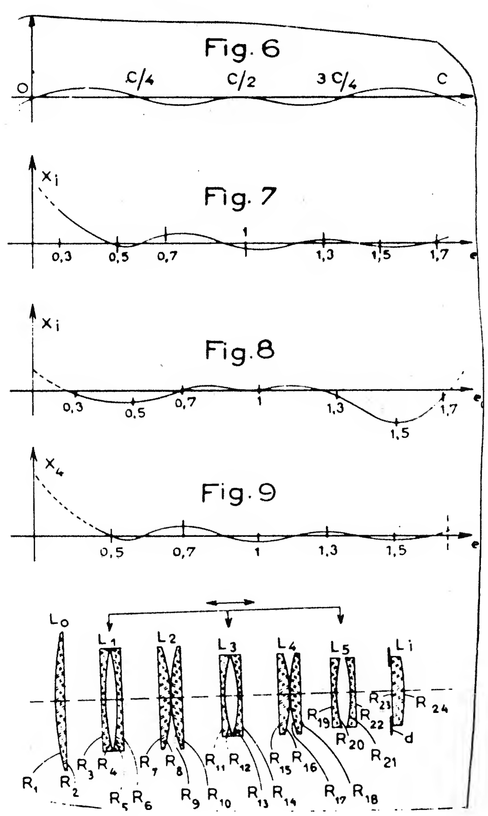

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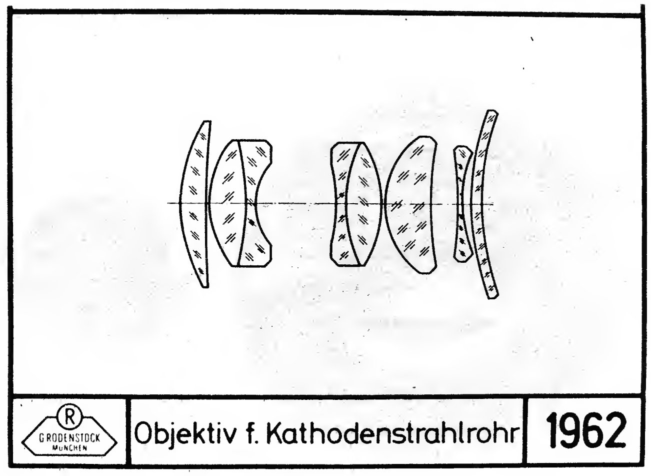
G. RODENSTOCK MÜNCHEN
Objektiv f. Kathodenstrahlrohr
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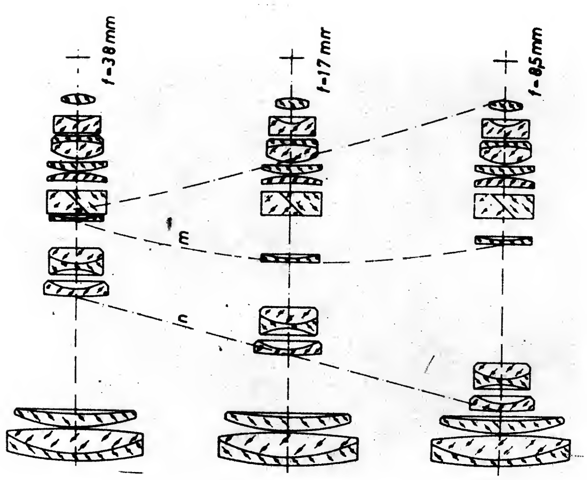
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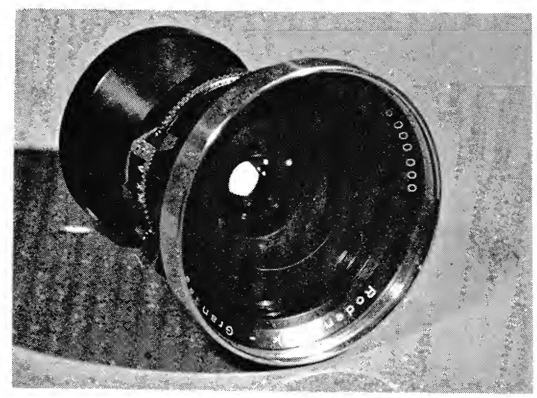

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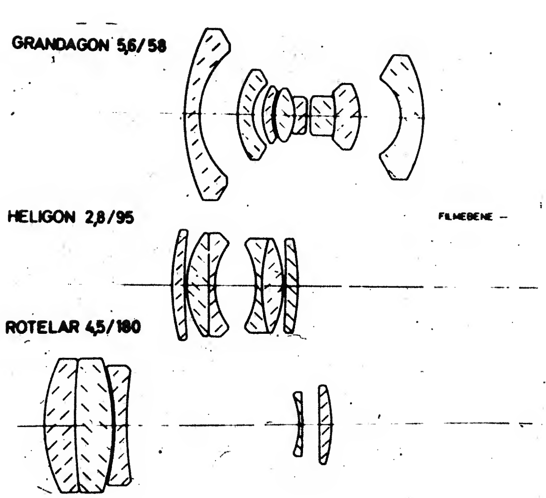
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HELIGON 2,8/95
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ROTELAR 4,5/180

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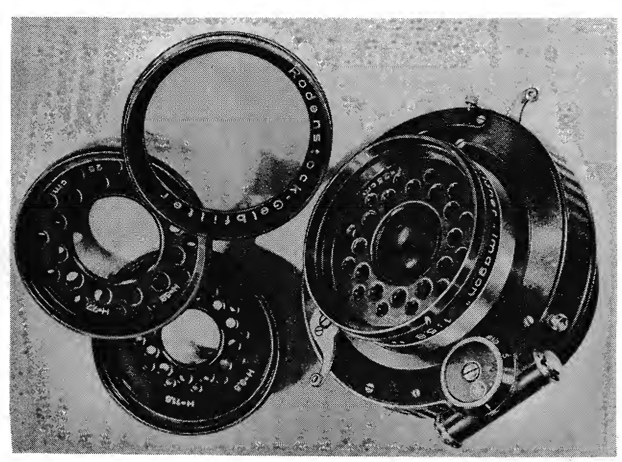

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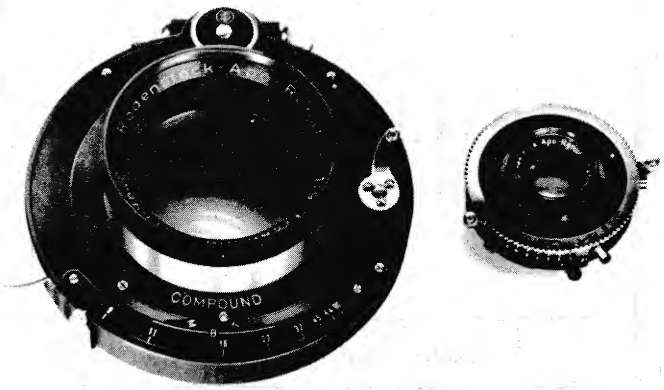
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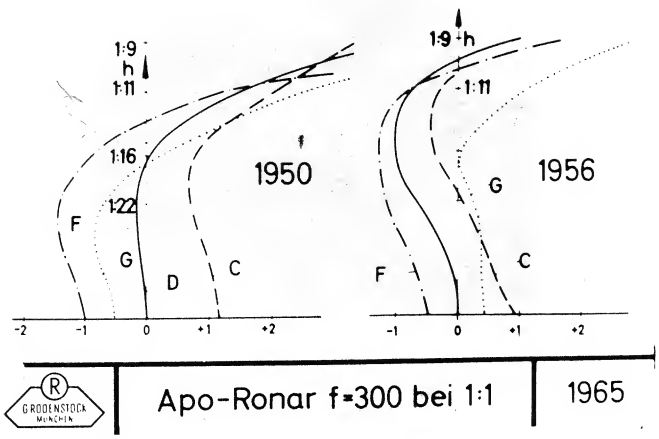
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Apo-Ronar f=300 bei 1:1
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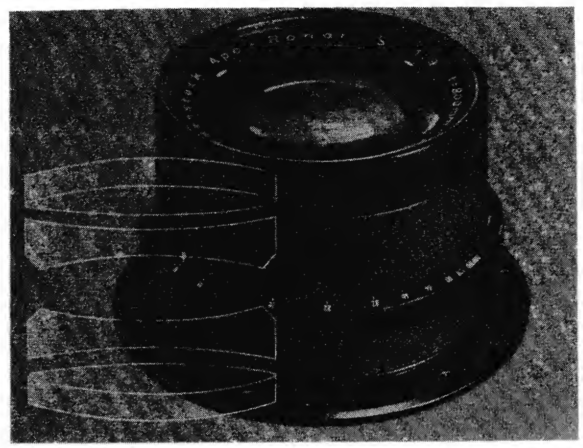

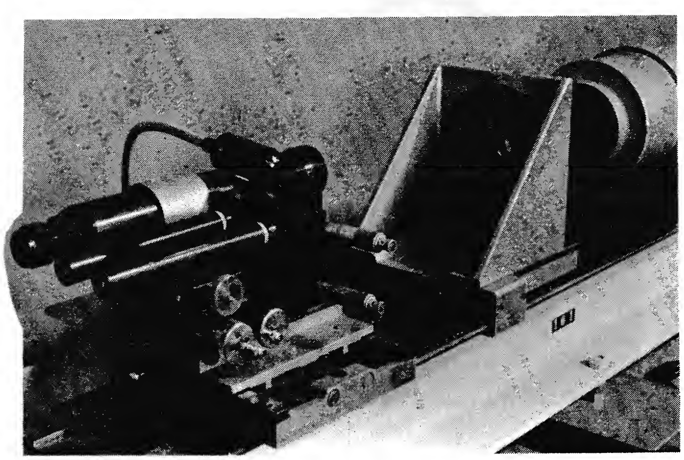

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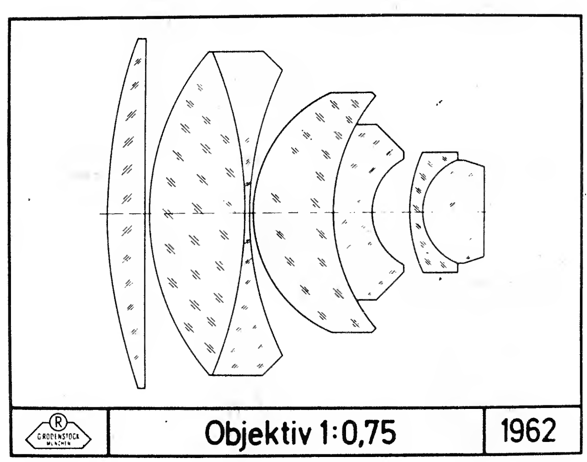
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